

HYDROGEOLOGY OF BASINS ON MARS

FINAL PROJECT REPORT

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SUMMARY OF RESEARCH

Work accomplished under NASA Grant NAG5-3870 is as follows.

FIDO: The FIDO Rover is a prototype for the Twin-MERs that will be operating on the surface of Mars in 2004. The primary work has been the analysis of FIDO field trials, as reported in Arvidson et al. [2000a, 2000b, 2001 (attached)], Backes et al. [2001], Jolliff et al. [2001], Li et al. [2001], Seelos [2001], Stoker et al. [2001], and Wiens et al. [2001]. The FIDO work was approved in December 1997 by the Planetary Geology and Geophysics (PGG) Program Manager (Patricia Rogers and then John Grant) as the focus of our efforts through the fall of 2000.

Correspondence Analysis Applied to Viking and Pathfinder Elemental Abundances: We have analyzed Viking Lander 1 XRFS and Pathfinder APXS data jointly using correspondence analysis, a dual Q and R-mode factor analysis technique. Results show that the Viking site chemistry is, in fact, consistent with an andesite whereas the Pathfinder site is consistent with a basaltic andesite (Larsen et al., 2000).

Simulated Annealing Method Applied to Inversion of Remote Sensing Data: Partly as a spin-off from FIDO efforts using Laser Induced Breakdown Spectroscopy (LIBS) and reflectance spectroscopy [Wiens et al., 2001] to constrain jointly the elemental abundances and mineralogy of rocks using stand-off remote sensing from rovers, graduate student Frank Seelos has been pursuing use of simulated annealing techniques as a way to invert hyperspectral data to estimate mineral proportions [Seelos, 2001; graduate student working with Arvidson and funded by Washington University]. This iterative method employs the downhill simplex method in multiple dimensions in conjunction with random perturbations of the model configuration to minimize the unmixing error residual [Press et al., 1993], either using simple linear unmixing or Hapke Photometric Function approaches. We have examined the use of the technique for estimation of mineral endmembers and proportions from TES data, with an emphasis on endmembers with relatively small signatures or proportions, e.g., sulfates in duricrust [e.g., Cooper and Mustard, 2001]. The current technique used for TES inversions utilizes the standard normal equation inversion to find the best fit of endmembers and areal proportions [Bandfield et al., 2000]. The problem is that as the number of endmembers grows the inversion rapidly approaches matrix singularity, e.g., after approximately 200 end members the normal equations cannot be inverted. Using simulated annealing this problem is avoided. We have been in touch with Steve Ruff, Arizona State University, and discussed with him the limitations of the technique currently used by the TES Team and we have offered use of our algorithm.

Initial Analyses of Sojourner Engineering Telemetry and Imaging Data: We have worked with Collaborator Albert Haldemann, Jet Propulsion Laboratory, on the use of Sojourner engineering data (along-track reports of Rocker-Bogie joint angles and wheel motor currents) and image data to infer surface slope angle distributions and soil properties (bearing strength, which depends on angle of internal friction and cohesion) for the regions traversed by the rover. We are analyzing the engineering data in concert with the IMP mosaics and terrain models provided by Collaborator Randy Kirk, USGS Astrogeology Branch, and digital elevation models generated by us from Sojourner stereo

images (using AMES Stereo Pipeline and Viz systems installed in our laboratory). The intent is to map the distribution of duricrust and its properties. The joint inversion of engineering data and image-based inferences (e.g., wheel track depths) to produce along-track estimates of terrain properties requires a system transfer function, one that we are developing with Haldemann and current FIDO/MER Engineers. The simulated annealing technique would then be used to infer properties.

Initial Analyses of Viking Lander Stereo Images: The two Viking Lander camera systems had a 0.822 m stereo baseline and produced excellent stereo image data. Yet, the only published digital elevation maps were generated by Liebes and Schwarz [1977] by manually selecting points in the image data. We have worked to develop a standard CAHVOR camera model [Yakimovsky and Cunningham, 1978] for the Lander Cameras and to import image data into the AMES Stereo Pipeline to be able to generate automatically elevation models from Viking Lander data. Initial products have, in fact, been generated. This work will allow us to map the distribution of duricrust in great detail for the two sites, including its distribution with local elevation and its areographic and stratigraphic associations with other soil types.

Initial Analysis of Hematite Deposits in Terra Meridiani: Work done over the past several months has also included mapping the hematite deposit in Terra Meridiani using Viking, MOC, and MOLA data [Arvidson et al., 2000c, Hynek et al., 2001]. The mapping has shown that the hematite material is a horizon exposed in a sequence of relatively flat-lying strata extending over 800 m in thickness and hundreds of kilometers in lateral extent (Figure 2A and Table 2). No lake shorelines or basins were identified and instead it appears as if the strata were draped over the Noachian cratered terrain surface after uplift of Terra Meridiani and subsequent fluvial erosion associated with formation of the Tharsis Plateau [Hynek and Phillips, 2001]. Airfall deposition by volcanic or aeolian processes seems to be the most viable mode of formation of the draped deposits, although deposition in a lacustrine environment cannot be ruled out [Christensen et al., 2000].

We are interested both in the genesis of the hematite unit and in the degree of induration of the exposed strata in the overall 800 m thick sequence, i.e., the extent to which duricrust has formed. Thus, we have recently moved to consideration of the remotely sensed properties of the units, using TES-derived thermal inertia (Figure 2B), albedo, and hematite index; MOLA pulse widths corrected for regional scale tilts; MOLA-derived elevations, and MOC Narrow Angle (NA) frames. For example, the stratum just beneath the hematite horizon has enhanced thermal inertia (Unit E, Figure 2A) and MOLA-derived roughness. MOC images show evidence for indurated deposits that have been differentially stripped by wind to produce rough surfaces.

Acquisition and Analysis of New Goldstone Radar Data: After discussions with and approval from David Senske, we have become deeply involved in acquisition and processing of new X-Band (3.5 cm) Delay-Doppler observations of the martian equatorial regions of Mars from the 70 m Goldstone system. This work is in collaboration with Albert Haldemann. A total of eighteen observation runs are scheduled between May 3 and July 13, 2001 covering five different regions, including the Terra Meridiani hematite deposits. Each observation run covers approximately eight degrees of latitude and

between forty and seventy-five degrees of longitude. In total, approximately 1.2 terabytes of radar data will be collected over the eighteen observation runs.

Four telescopes are being used for receipt of scattered data in an interferometric mode to allow resolution of the north-south ambiguity inherent to radar measurements and mapping of Hagfors parameters (quasi-specular RMS slopes and Fresnel Reflection Coefficients) into discrete spatial cells. By using four stations the ambiguous strip of data is reduced to the middle 2.5 degrees of latitude. The remainder of the strips will be imaged at relatively high resolution for Earth-based observations. Using existing combinations of software and hardware, the maximum attainable resolution will be about 20 km. However, we are investigating the use of new sampling devices and processing techniques that may allow an even higher resolution, on the order of 5 km. Currently, the data sampling hardware automatically sums between four and eight of the observations to increase the signal to noise ratio at the higher ranges and frequencies. Summing is done across the entire observation, including the sub-radar point regions where the signal to noise from a single observation is very high. We are examining the possibility of using a summing technique that will vary across range and frequency, enabling a smaller cell width where it can be supported by the data signal/noise ratio.

We are also working to integrate MOLA derived topography in the modeling code. The current modeling method uses an iterative, template-based technique to fit the target range and the two unknown Hagfors parameters. The range to the reflecting cell is estimated and then the measurements from the four stations are combined to create a maximum likelihood function (MLF). By optimizing this function, the best values for the unknown physical constants are derived. One of the largest sources of error in this technique is related to the estimation of the range. Some regions on the surface of Mars have a very low reflectivity (especially within the 'Stealth' feature). The current algorithm to derive range attempts to identify the first returned echo from each cell and thus calculate the range. But, with the low reflectivity regions, the first echo can be so low as to be indistinguishable from the noise. Our new technique uses MOLA-derived topography to eliminate the need for estimating the range to target. Thus the error from range estimation is removed, and the computational overhead for the calculation of the remaining two parameters is greatly reduced. The technique remains the same as before, forming the MLF function from the combination of signals from the four receiving stations and optimizing the estimation of the Hagfors Parameters.

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